Professional Development Short Course On:

Fundamentals of Rockets & Missiles

Instructor:

Edward L. Keith

ATI Course Schedule: **http://www.ATIcourses.com/schedule.htm**

ATI's Fundamentals Of Rockets & Missiles: **http://www.aticourses.com/fundamental_rockets.htm**

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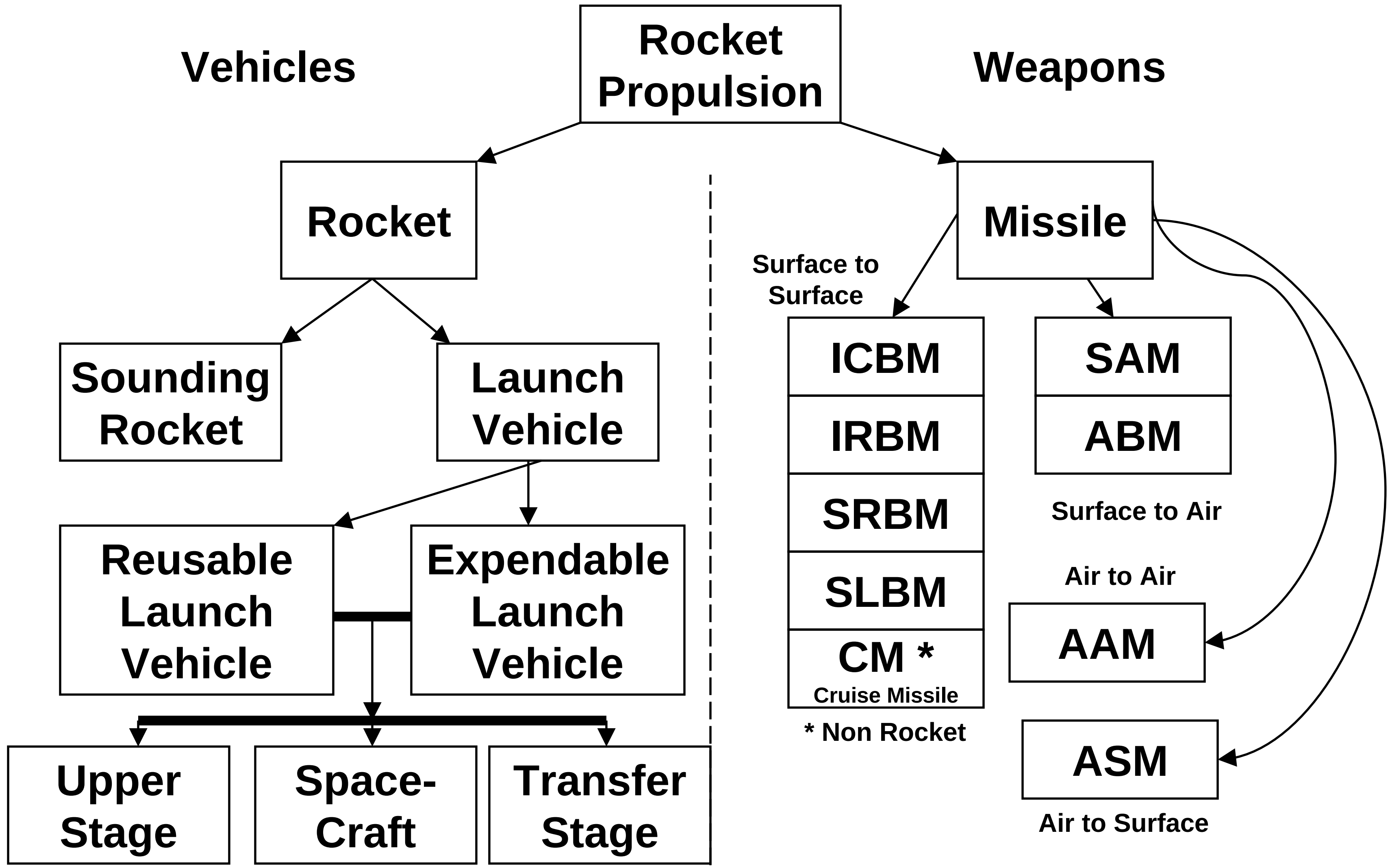
Fundamentals of Rockets and Missiles Class Sampler

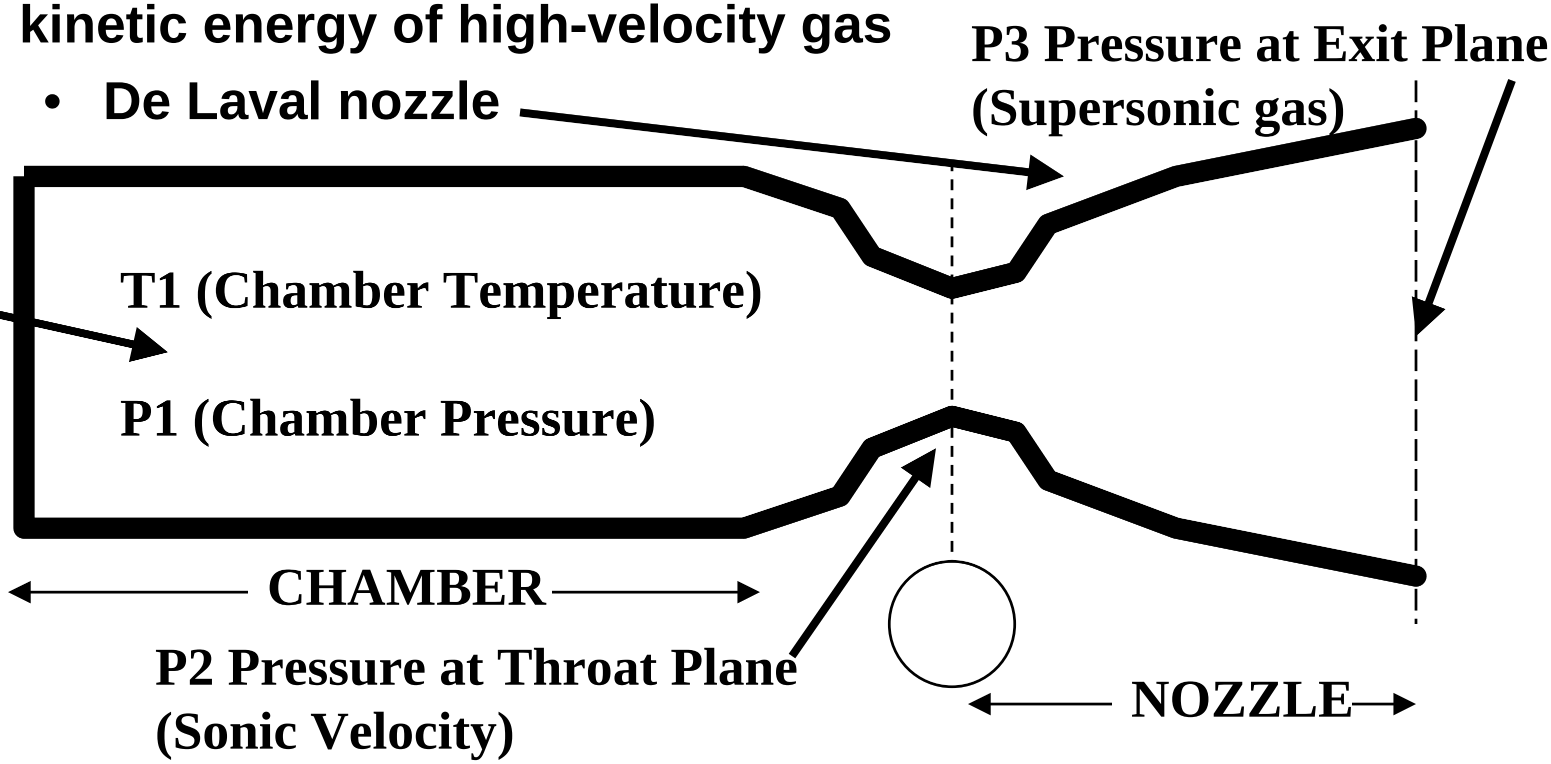
This is an introductory class in rocket systems used as launch vehicles and as weapons. Basic rocketry principles are introduced to provide a foundation of the principals of solid and liquid rockets. Existing systems are discussed to understand why the systems evolved to their present state.

Terminology and Conventions



Rocket Engine and Nozzle

- A combustion chamber (or motor case) is the device to burn a fuel and oxidizer [or decompose a mono-propellant] to create hot, high-pressure gas with high thermal energy
- A throat and nozzle is a device to accelerate hot gas, causing the thermal energy of that gas to be converted into kinetic energy of high-velocity gas
  - De Laval nozzle



Why Exhaust Gasses are Fuel-Rich

- The performance (specific Impulse) of a rocket engine is dependant on the temperature and molecular weight of the combustion gasses

$$Isp = k\sqrt{T/_{MW}}$$

- The highest performance through higher temperature has limits in chemical energy, and engine cooling capacity
- There are, however, strategies that reduce gas molecular weight with only small sacrifice in temperature
  - Fuel rich gasses like H_2 [MW=2] and CO [MW=28]) are significantly lighter than H_2O [MW=18] and CO_2 [MW=44]
    - The mixture ratio is selected to leave partially burned fuel (H_2, CO, etc.) in the exhaust for increased performance
- The bright flame from rockets is afterburning

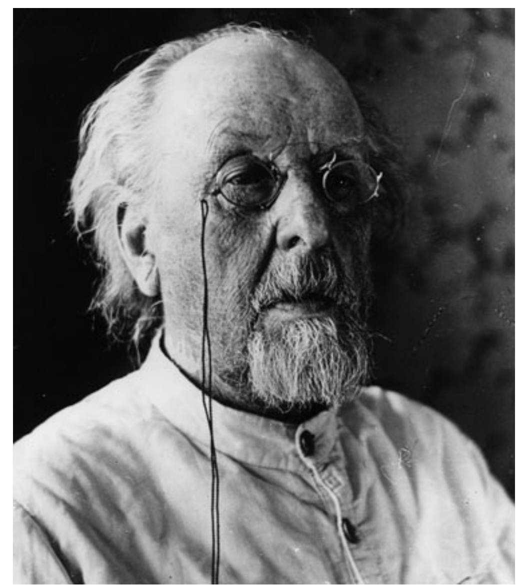
Introducing the Rocket Equation *

- Rocket Equation is essential for evaluation of any rocket system
- Solves the Ideal Velocity Change (Delta-V or ΔV) given the rocket engine efficiency (specific impulse or I_{sp}) and the ratio of the mass at ignition to the mass at burnout

Ln (10) = 2.3
Ln (4) = 1.386
Ln (2) = 0.693

$$\Delta V = I_{sp} * g * \ln (M/m)$$

- Where:
  - Delta-V is velocity (f/s [English]
  - g is acceleration of gravity (32.2 f/sec^2)
  - "ln" is the natural logarithm function
  - M is the initial Mass (Big M)
  - m is the final mass (Little M)



* 1897 "The Tsiolkovsky Rocket Equation"

Staging Theory & the Rocket Equation

- **The term “Rocket Trains’ describing staging theory was described by Tsiolkovsky * (1857-1935)**
  - **Higher velocity with more payload and less sensitivity**
  - **Single Stage $\Delta V = Isp * g * \ln(M/m)$**
    - **For M/m = 2 and Isp = 300, ΔV = 6,696 f/s**
    - **For M/m = 4 and Isp = 300, ΔV = 13,392 f/s**
    - **For M/m = 6 and Isp = 300, ΔV = 17,308 f/s**
    - **For M/m = 8 and Isp = 300, ΔV = 20,087 f/s**
    - **For M/m = 10 and Isp = 300, ΔV = 22,243 f/s**
    - **For M/m = 22.33 and Isp = 300, ΔV = 30,003 f/s**
- **Remember, it takes about 30,000 f/s to achieve LEO and m is both dry rocket structure <u>and usable payload</u>**

*** 1929 “The Space Rocket Trains” by Tsiolkovsky**

Extending the Rule to Engine T/W

- **The two-thirds root rule can be extended to a key rocket engine parameter – Thrust to weight ratio (T/W)**
- **Rule (conjecture) is based on adjusted volume flow rate**
  - **Adjusted to the performance of that flow**

$$T/W_1 = T/W_2 \times (BD_2/BD_1)^{0.6667} \times (Isp_2/Isp_1)$$

- **The correction seems to work, and again is explained by the Volume to Surface area ratio**

$$TW1 = TW2 * \left({}^{Isp2}/_{Isp1} \right) * \left({}^{BD2}/_{BD1} \right)^{0.667}$$

The algorithm may be conjecture, but it seems to fit reality better than any other rule.

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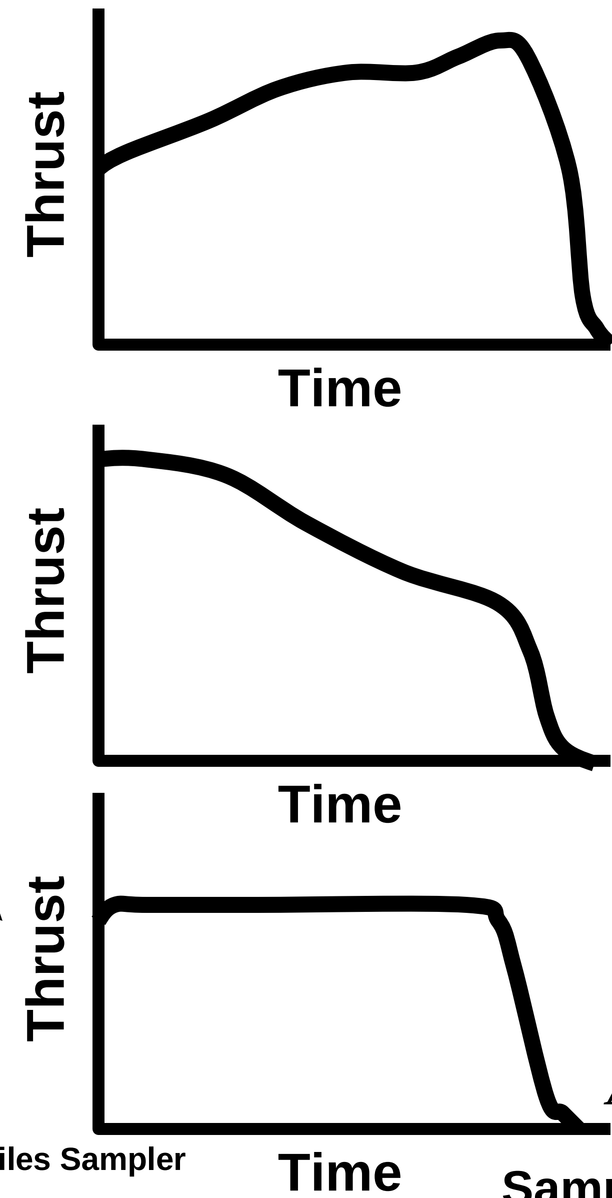
Hydrazine – Top Mono-Propellant

- **Mono-propellant hydrazine decomposes to Ammonia, Nitrogen and Hydrogen**
  - **Catalyst "Shell 405" is generally accepted best material**
- **The temperature and species of the decomposed Hydrazine is dependant on the catalyst and other factors**
  - **$2N_2H_4 \Rightarrow 2NH_3 + N_2 + H_2$ @1,880 F**
    - **Minimum Decomposition**
  - **$N_2H_4 \Rightarrow N_2 + 2H_2$ @1,100 F**
    - **Maximum Decomposition**
- **Hydrazine achieves about 235 seconds specific impulse in practical thrusters**
- **High Density (1.01 g/cc)**
- **Permanently storable**

Propellant Grains Can Be Tailored

- **Progressive**
- **Regressive**
- **Neutral**



Impulse

Area under the Curve (Pound-Seconds) [Propellant Weight x Isp]

- **Thrust profile determined by Grain Geometry**

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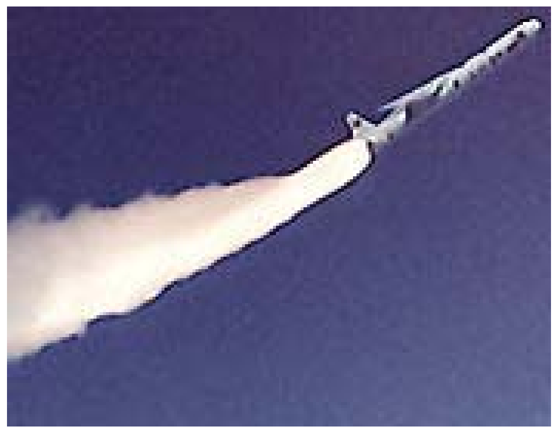
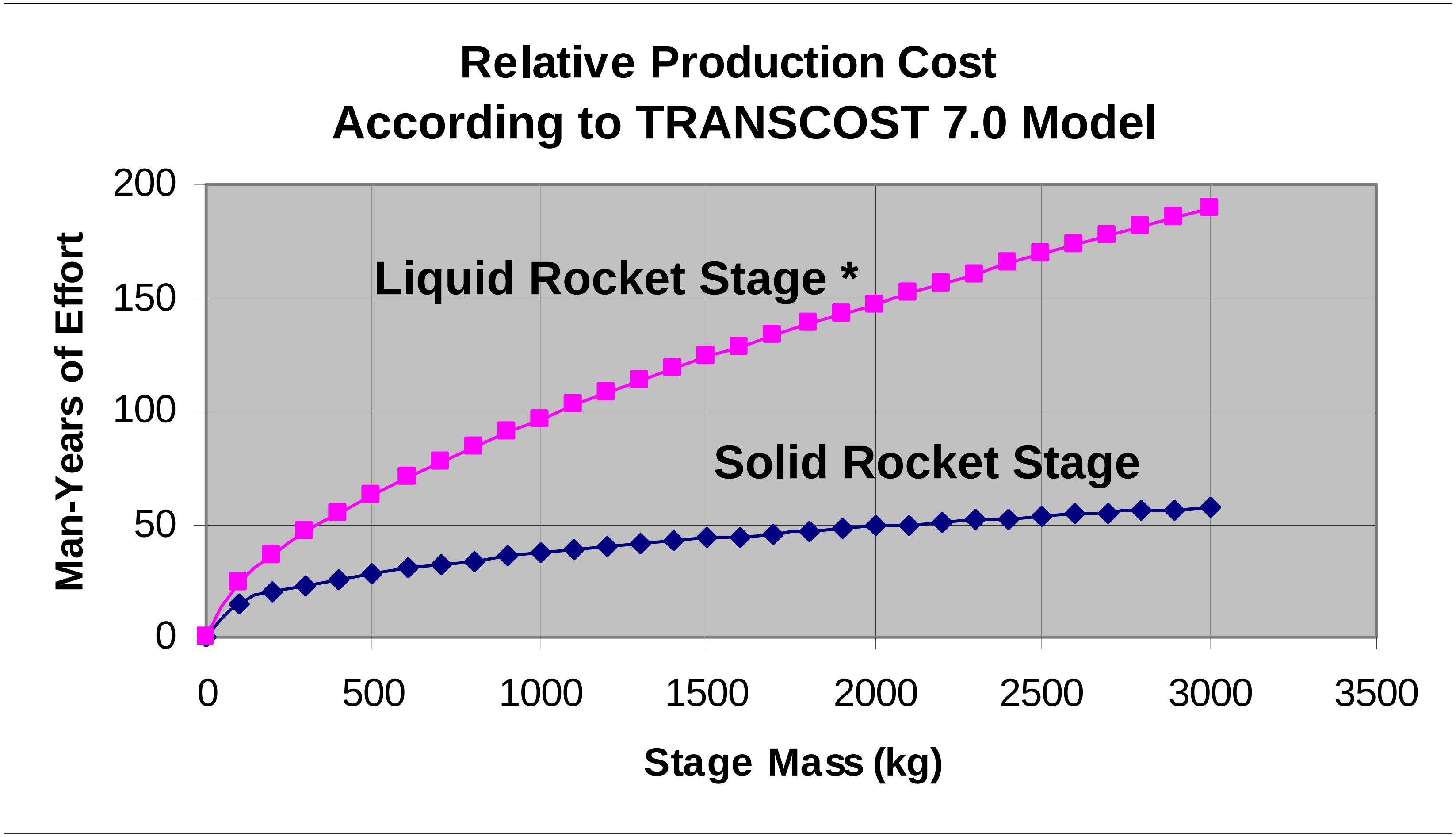
All Solid Rocket Motor Launch Vehicle

- The Taurus (Right) is one of three all-solid rocket motor American launch vehicles
  - Stages two, three and four (left) are the same as are used for stages one, two and three on the Air-Launched Pegasus



http://www.atk.com/homepage/products/

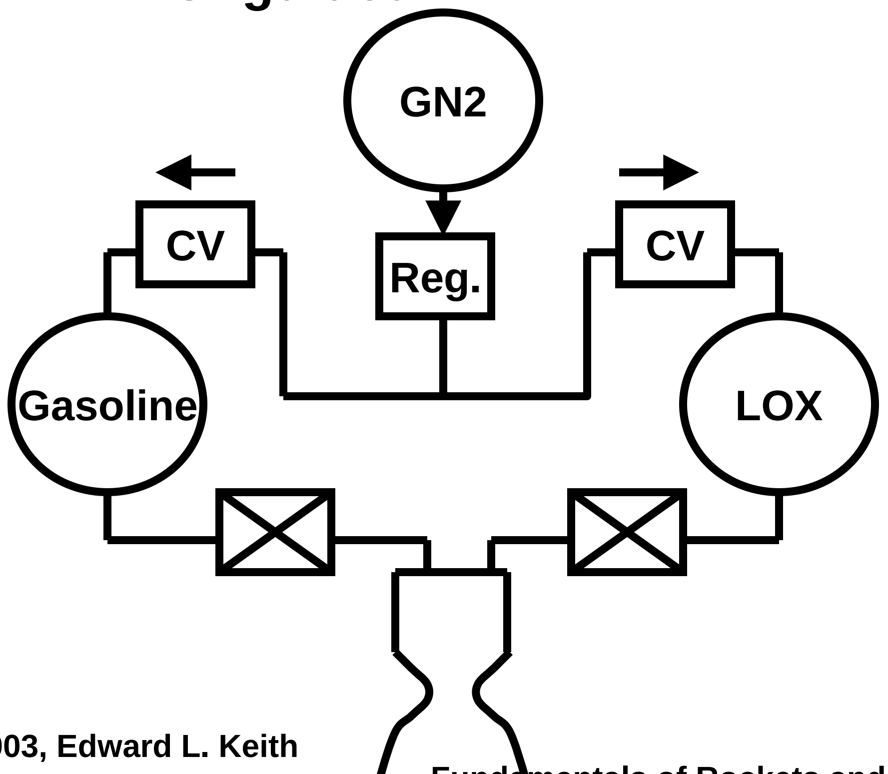
Relative Production Cost



* 20% Engine, 80% Stage

Liquid Rockets are New Technology

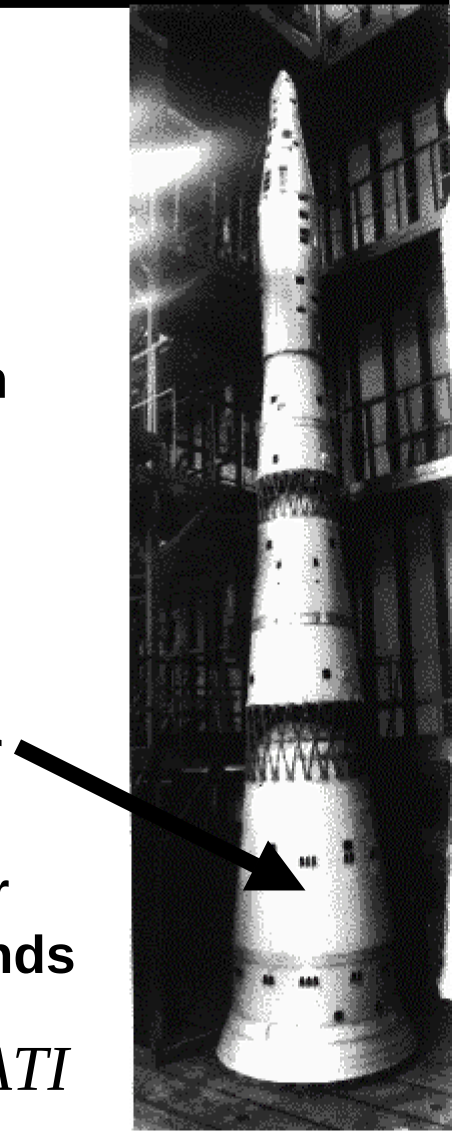
- **Robert Goddard (below) was an early pioneer of liquid rocket propulsion**
  - **Gasoline and liquid oxygen**
  - **Pressure-fed**
  - **Unguided**



N-1 Soviet Moon Rocket Strategy

- The Soviet N-1 Moon Rocket also shows typical Russian features
  - Stage 1 used 30 NK-33 engines
  - Stage 2 used 8 NK-43 engines
    - Similar to NK33 but higher expansion
  - Stage 3 used 4 NK-39 engines
  - Stage 4 used 1 1 NK-31 engines
    - Similar to NK-39
- Note that most Russian rockets (Soyuz, Proton, N-1) tend to be tapered, with a fatter base than the middle and upper sections
  - Aerodynamic stability increase for better control during passage through high winds aloft near max-q

– Four failed flights (1969-1972)



http://www.aerospaceguide.net/n-1.html

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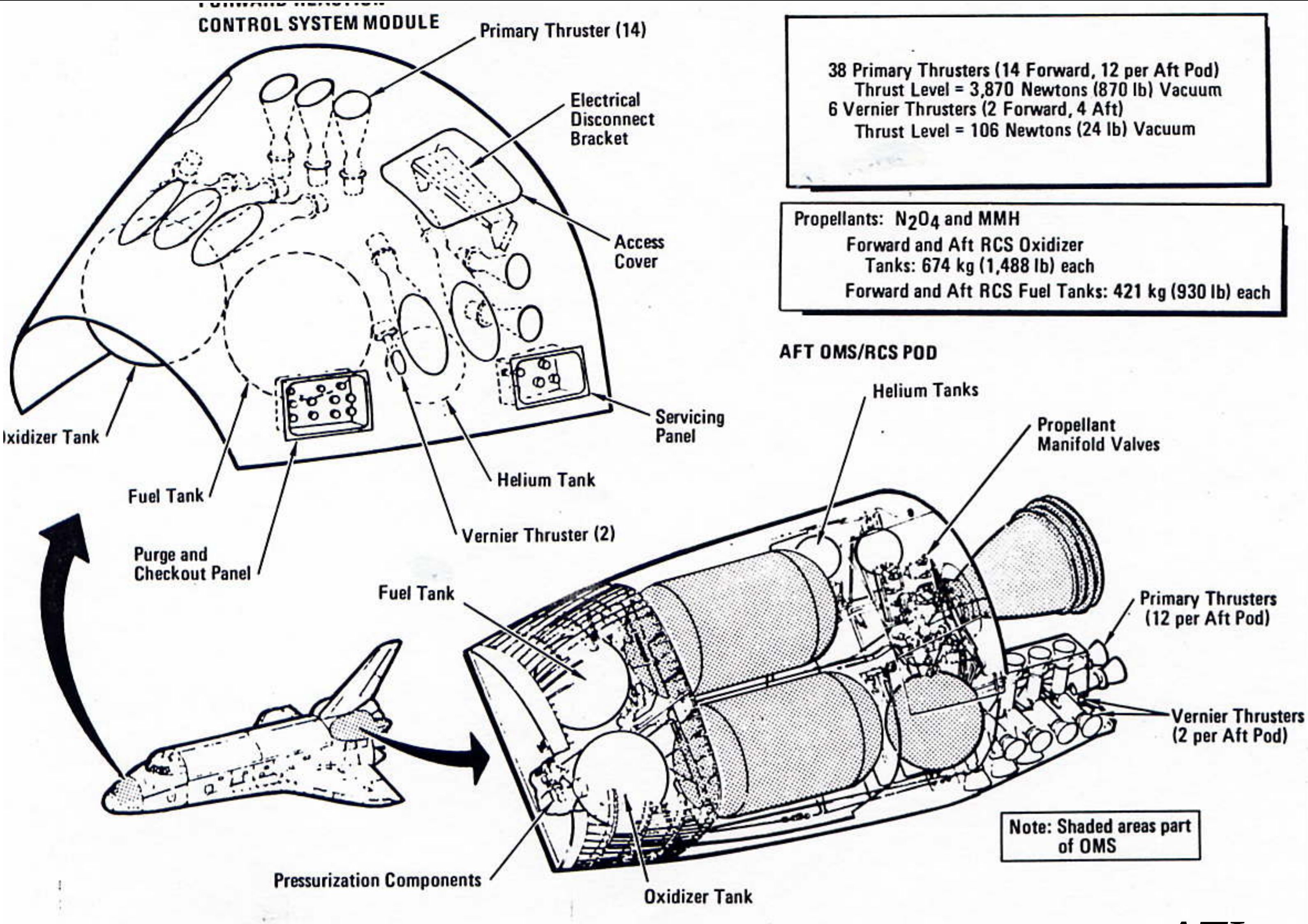
Current Space Shuttle RCS



Reaction Control System

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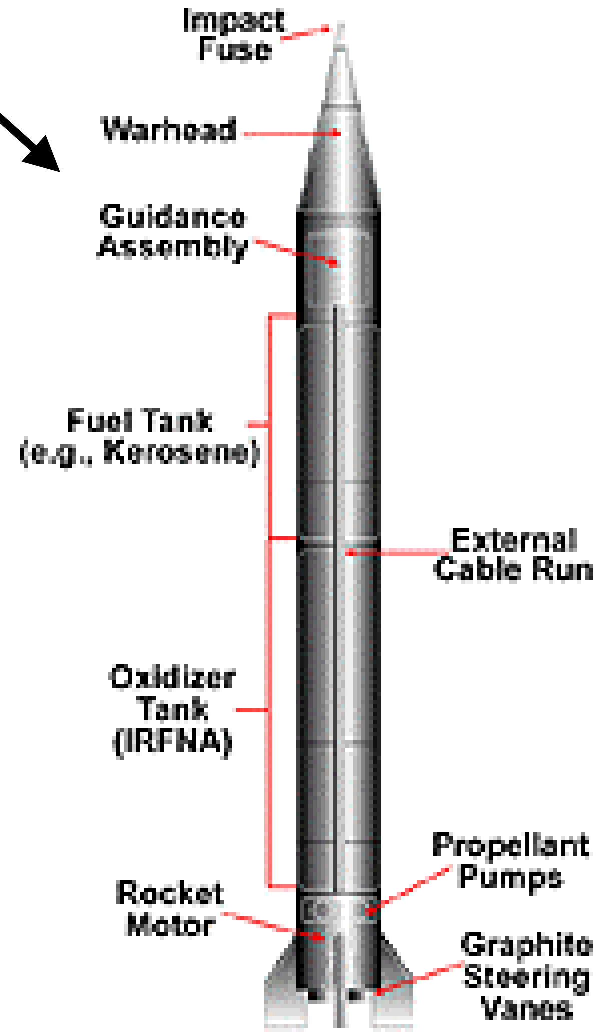
Surface to Surface Missile Proliferation

- **19 Countries with Scud Missiles**
  - **Belarus, Bulgaria, Czech Republic, Hungary, Poland, Romania, Russia, Slovakia, Ukraine, Egypt, Iran, Iraq, Libya, Syria, Yemen, Afghanistan, Kazkhastan, Tajikistan and North Korea**
- **North Korean Taepo Dong is a Third World ICBM**
  - **Technology exported to Iran?**
    - **Which has an aggressive Nuclear Program**



Microcosm – Hardware Demonstration

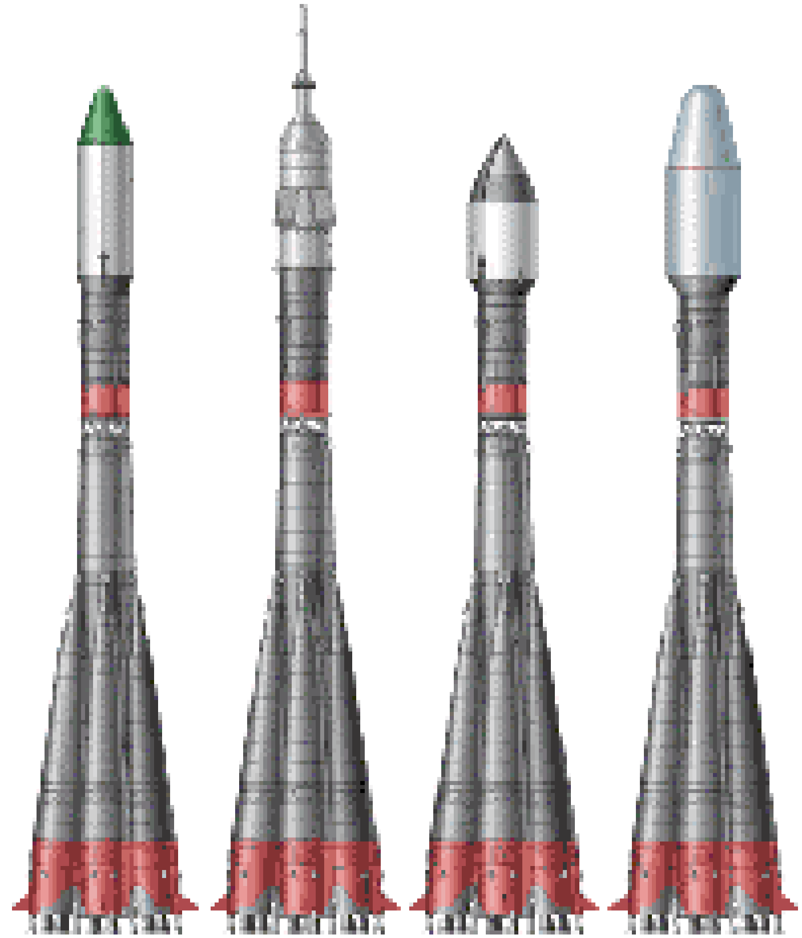
Scorpius® is a new generation of expendable launch vehicles intended to reduce the cost of launch to orbit by a factor of 5 to 10. The Scorpius® program is a total "clean-sheet" development using new technologies for pressure-fed, LOX/Jet-A propellants, all new low cost ablative engines, and GPS/INS guidance/control. Funding for the ongoing Scorpius program has been provided primarily by the Air Force, Ballistic Missile Defense Organization (BMDO), NASA, and Microcosm internal R&D.

http://www.smad.com/ns/nsframessr3.html

Scorpius –According to Microcosm

Soyuz Launch Vehicle

- **No space launch vehicle has flow to more than the Russian "Soyuz" family**
  - **Sputnik 1 (1957)**
  - **All Russian Manned Missions**
  - **A flight per week on average for 22 years**



http://www.spaceandtech.com/spacedata/elvs/soyuz_sum.shtml

Relationships Between Safety and Reliability

- **Safety and Reliability are closely related**
  - **If a system failure causes loss of property, injury or loss of life, it is a Safety Problem**
  - **If a system failure causes premature loss of the rocket, or causes the mission to fail, it is a Reliability Problem**
    - **Common denominator can be unexpected failures**